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APOLLO LOGISTICS SUPPORT SYSTEMS MOLAB STUDIES

ELECTRONIC EQUIPMENT PACKAGING FOR A LUNAR MOBILE LABORATORY

Prepared under Contract No. NAS8-5307 by

J. W. Lombard

HAYES INTERNATIONAL CORPORATION
Missile and Space Support Division
Apollo Logistics Supporrt Group

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NASA - GEORGE C. MARSHALL SPACE FLIGHT CENTER
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ELECTRONIC EQUIPMENT PACKAGING FOR A MOBILE LABORATORY

ABSTRACT

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This report presents the temperature limitations of the types of components which could be used in a Lunar Mobile Laboratory (MOLAB) and compares these temperature limits with the MOLAB mission temperatures.

A list of the basic components which could be used to make up the required electronic units is included, and the non-operating temperature limits of these components are tabulated.

A comparison is made of the non-operating temperature limits of the components with the MOLAB mission temperatures.

There is a discussion of the factors which will effect the operating temperatures of the components and the relationship of these factors with the MOLAB mission temperatures.

Author

1.0 OBJECTIVE

The purpose of this report is to establish the necessity for controlling the temperature of the MOLAB electronic equipment and to determine some of the temperature limitations of the equipment which can be used as a starting point for future studies.

Environmental factors other than temperature have not been included in this study. It has been assumed that the temperature effects can be isolated from other environmental factors. The effects of high vacuum or humidity can be eliminated by hermetic sealing; the effects of shock and vibration by shock isolators.

Although the effect of penetrating radiation has not been included, this could be a critical problem area. Some information has been received regarding the resistance of components to radiation, but not enough to be significant for inclusion in this report.

2.0 TYPES OF ELECTRONIC COMPONENTS

The first step in determining the temperature limits of the MOLAB electronic equipment is to establish the types of components that will be used. An attempt has been made to determine the basic components such as transistors and resistors, which will have to be used in the various MOLAB systems. This approach permits an analysis of the temperature limitations without being limited to functional units produced by specific manufacturers. It also pinpoints the critical basic components which control the capabilities of the complete units.

The major source of information for establishing a list of basic components was individual studies made on the various MOLAB systems. Electronic catalogues also were used as a source of types of components.

A list of the MOLAB's systems and sub-systems is shown below:

1. Astrionics
    a) Communications - microwave and low frequency
    b) Telemetry
    c) Video
    d) Navigation
    e) Command & Control
2. Power
    a) Power Supplies
    b) Power Distribution

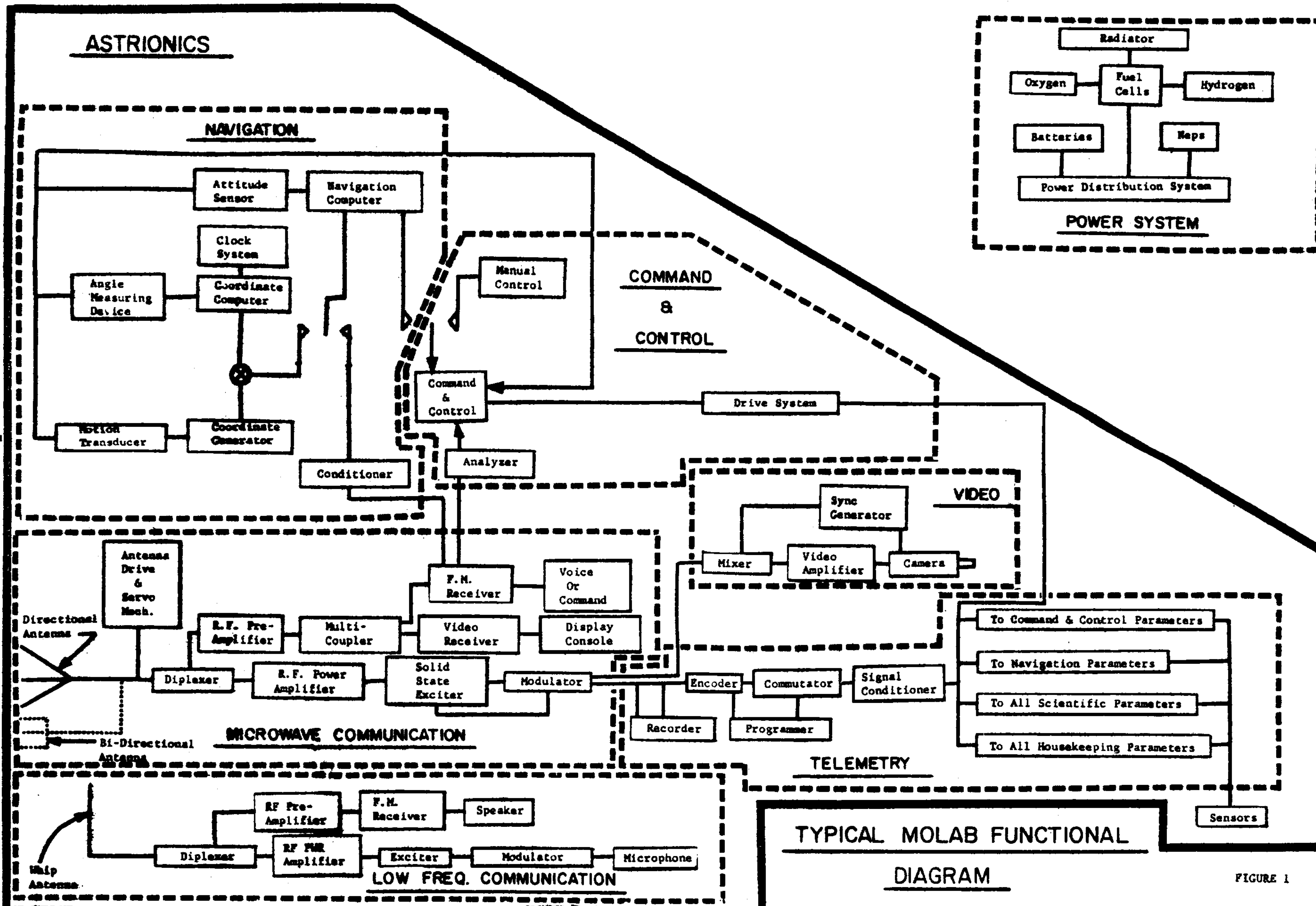
It should be noted that the studies which are being conducted on the above systems are parametrical; therefore, the systems examined here are not necessarily those which eventually will be used for the MOLAB. It is anticipated however, that changes in the system concepts will not materially effect the types of basic components used.

Figure 1 is a functional diagram of a typical concept of the MOLAB electronic systems. Each block represents a functional unit of the system which might represent part of a physical unit or several physical units. A brief description of these systems will follow, along with a list of their basic components.

2.1 ASTRIONICS

2.1.1 COMMUNICATIONS

Two types of communication systems may be used with the MOLAB. The RF microwave system most probably will be used as the link between the earth and the MOLAB, and the low frequency system could be used as the link between the MOLAB and a roving astronaut. The following is a listing of the functional units and the basic types of components used in a typical communication system:



TYPICAL MOLAB FUNCTIONAL DIAGRAM

FIGURE 1

a) <u>RF Microwave</u>

<u>Transmitter (Amplifier and Exciter)</u>

Traveling Wave Tube

Microwave Planar Triodes

Micro-Circuits

Insulators

Stabilitrons and Amplitrons (Crossed Field Tubes)

Magnets

Backward Wave Amplifiers

Resistors

Transistors

Capacitors

Diodes

Transformers

Crystals, Frequency Control

Etched Circuitry

Wire

Chokes, Filter

<u>Modulator</u>

Resistors

Transistors

Capacitors

Diodes

Transformers

Crystals, Frequency Control

Etched Circuitry

Wire

Chokes, Filters

Micro-Circuits

Insulators

Reactance Tube

Diplexer

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

RF Preamplifier

*Backward Wave Oscillator Amplifier

*Traveling Wave Amplifier

*Microwave Triodes

Resistors

* Only one of these three would be used - probably the Traveling Wave Amplifier.

Transistors

Capacitors

Etched Circuitry

Wire

Micro-Circuits

Insulators

Multicoupler

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

FM Receiver

Resistors

Transistors

Capacitors

Diodes

Transformers

Chokes

Etched Circuitry

Wire

Micro-Circuits

Insulators

<u>Video Receiver</u>

Resistors

Transistors

Capacitors

Diodes

Transformers

Chokes

Etched Circuitry

Wire

Micro-Circuits

Insulators

<u>Display Console</u>

Speaker

Cathode Ray Tube

<u>Servo-Drive</u>

AC, DC, Motor

Gears

Pulleys

Belts

Relay

<u>Coaxial Cable</u>

<u>Antenna</u>

b) Low Frequency

Diplexer

Same as RF Microwave

RF Power Amplifier

Same as RF Microwave

Transmitter

Same as RF Microwave

RF Pre-Amplifier

Same as RF Microwave

FM Receiver

Same as RF Microwave

Display Console

Speaker

Microphone

2.1.2 TELEMETRY

The telemetry system is the link between the parameters being measured and the RF microwave communication system. The following is a list of the functional units and the basic types of components used in a typical telemetry system:

Encoder

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

<u>Multiplexer</u>

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

<u>Signal Conditioner</u>

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

Batteries (Reference Voltage)

<u>Programmer</u>

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

Crystals, Frequency Control

<u>Tape Recorder</u>

Magnetic Tape

Motor, AC or DC

Lubricant

Belts

Gears

Bearings

Erase / Record / Reproduce Heads

Insulators

Permanent Magnets

Reels

Rollers

Capstans

Springs

Oscillator

Resistors

Transistors

Capacitors

Etched Circuitry

Wire

Micro-Circuits

Latching Relay

Photo Diodes

2.1.3 VIDEO

The video system will provide the visual link between the earth and the MOLAB. The following is a listing of the functional units and the basic types of components used in a typical video system:

<u>Cameras</u>

- Lens
- Shutter
- Vidicon Tube
- Deflection Coils
- Iris
- Optical Filters

<u>Synchronous Generator</u>

- Crystals, Frequency Control
- Resistors
- Transistors
- Capacitors
- Diodes
- Etched Circuitry
- Wire
- Micro-Circuits
- Insulators
- Inductors

Video Amplifier

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

Inductors

Mixer

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

Servo Mechanism (For Camera Positioning)

AC or DC Motor

Gears

Pulleys

Belts

Bearings

Lubricants

Relay

Servo Amplifier

- Resistors
- Transistors
- Capacitors
- Diodes
- Etched Circuitry
- Wire
- Micro-Circuits
- Insulators

2.1.4 NAVIGATION

The navigation system will provide a means for establishing the position of the MOLAB on the lunar surface, and will operate in conjunction with the control system and the communication system. The following is a list of the functional units and the basic types of components used in a typical navigation system.

Motion Transducers

- Odometer
- Tacometer
- Accelerometer

Navigational Computer

- Resistors
- Transistors
- Capacitors
- Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

Inductors

Clock System

Transistors

Resistors

Diodes

Capacitors

Etched Circuits

Crystal Controlled Oscillator

Indicators

Wire

Micro-Circuits

Insulators

Attitude Sensor (Gyros)

Bearings

Lubricants

Coordinate Computer

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

Inductors

Coordinate Generator

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

Inductors

Conditioner

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

Inductors

Angle Measuring Device

2.1.5 COMMAND AND CONTROL

The command and control system provides the means for controlling the various functions of the MOLAB. The following is a list of the functional units and the basic types of components used in a typical command and control system.

Analyzer

Rectifier

Relays

Resistors

Transistors

Capacitors

Diodes

Etched Circuitry

Wire

Micro-Circuits

Insulators

Controls

AC or DC Motors

Gears

Pulleys

Bearings

Belts

Lubricants

Indicators

Transducers

2.2 POWER SYSTEM

2.2.1 POWER SUPPLY

The power supply provides the electrical power for all the other MOLAB systems. The following is a list of the functional units and the basic types of the components used in a typical power supply.

- Battery Silver-Zinc
- Fuel Cell
    - Solenoids
    - Valves
    - Chemicals
- Flow Control System
    - Solenoids
    - Valves
    - Pressure Switches
    - Transducers
- Tankage
    - Hydrogen
    - Oxygen
- NEPS (Nuclear Electric Power Subsystem)
- Radiator
    - Valves
    - Sensors (thermal)
    - Pressure Switches

2.2.2 POWER DISTRIBUTION SYSTEM

The power distribution system delivers the power from the power system to the other MOLAB systems. The following is a list of the functional units, and the basic types of components used in a typical power distribution system.

<u>Control Console</u>

Switches

Wires

Valves

Jacks

<u>Status Display</u>

Lamps

Wires

<u>Regulators</u>

Resistors

Transistors

Capacitors

Diodes

Transformers

Etched Circuitry

Wire

Micro-Circuits

Insulators

Convertors

Transistors

Capacitors

Diodes

Resistors

Etched Circuitry

Wire

Micro-Circuits

Insulators

Inductors

Inverters

Transformers

Transistors

Capacitors

Diodes

Resistors

Etched Circuitry

Wire

Micro-Circuits

Insulators

Inductors

Relays

Wiring

Switches

Circuit Breakers

3.0 MOLAB MISSION TEMPERATURES

The actual determination of temperatures related to the MOLAB mission is being accomplished by other studies. The purpose of presenting them here is to permit a comparison of their extremes with the temperature limitations presented in sections 4.0 and 6.0. These temperatures are taken from preliminary information; therefore, they are subject to change. The temperatures within the MOLAB cabin are especially unreliable since the MOLAB configuration has not been finalized.

It is assumed that most of the electronic equipment will be contained within the MOLAB cabin. There will be some exceptions, such as the antenna and the bulky power supplies, which probably will be located outside the cabin.

A list of the MOLAB mission phases and the temperatures at different locations relative to the MOLAB are shown below:

Pre-Launch Conditions - Packaged

Packaged	-54°C to +71°C
Unpackaged	-31°C to +43°C

Launch and Boost

Uncontrolled Cabin	-18°C to +71°C
Ambient Sea Level	- 1°C to +38°C
Equipment Bay	-18°C to +71°C

Space Flight - Translunar

Vacuum Equipment Bay	-18°C to +71°C
Controlled Cabin (O_2)	+21°C to +27°C
Uncontrolled Cabin	-18°C to +71°C
Lunar Surface	-162°C to +127°C
Space	-273°C

Lunar Descent

Vacuum Equipment Bay	-18°C to +71°C
Controlled Cabin (O_2)	+21°C to +27°C
Lunar Surface	-162°C to +127°C
Space	-273°C

Lunar Stay

Vacuum Cabin and Equipment Bay	-18°C to +71°C
Controlled Cabin (O_2)	+21°C to +27°C
Lunar Surface	-162°C to +127°C
Space	-273°C

4.0 NON-OPERATING TEMPERATURE LIMITS

The non-operating limits will be established first, since there are fewer variables to consider than for those under operating conditions. These limits are the temperatures which the component can withstand while in the dormant state without causing a significant reduction in the reliability or capabilities when under operating conditions.

The main source of information on temperature limitations has been component manufacturers; a large amount of literature from this source has been examined to obtain the information presented. Most of the components are designed to meet certain military specifications; therefore, most of the temperature limitations correspond to these specifications.

In order to determine the capabilities of these components to withstand temperatures of a greater extreme than specified by the military specifications, a form letter was prepared which requested information on the extreme environmental limitations of the manufacturer's components. Approximately 500 of these letters were mailed out; at the present time there have been over 100 replies. Useful information has been obtained from these replies, but, in most cases, the reported temperatures correspond to existing military specifications.

The following is a list of the components which conceivably could be used in the MOLAB, along with their non-operating temperature limitations. This list includes most of the components listed under sections 2.1 through 2.7, along with others which may have MOLAB applications. There are some components listed that do not have temperature limits shown, since the information was not available or because it was dependent on the detail design of the equipment. In many cases the environmental limitations of the components are restricted because there has been no necessity to develop a more rugged component. No effort has been made to predict the future state-of-the-art. One objective of this report is to pinpoint the areas in which an improvement in the state-of-the-art would be beneficial.

Accelerometer	-195°C to +260°C
Antenna	
Batteries (Reference Voltage)	4°C to 40°C
Batteries - Silver Zinc	-29°C to +74°C
Batteries - Silver Cadmium	-40°C to +60°C
Batteries - Nickel Cadmium	-50°C to +70°C
Bearings	+240°C
Belts	
Cable	-195°C to +316°C
Cable Coaxial	-90°C to +260°C
Cameras, TV	-65°C to +85°C
Capacitors, Ceramic	-65°C to +200°C
Capacitors, Tantalum	-85°C to +125°C
Cathode Ray Tube	0°C to +55°C
Chokes	-55°C to +125°C
Choppers	-55°C to +150°C
Circuit Breakers	-54°C to +71°C
Coils, Deflection	
Connectors	-198°C to +427°C

Crossed Field Tubes	
Crystals, Frequency Control	-65°C to +125°C
Delay Lines, Distributed, Constant, Fixed	-65°C to +125°C
Diodes, Germanium	-65°C to +90°C
Diodes, Silicon	-65°C to +200°C
Etched Circuitry	
Filters, Band Pass	-65°C to +100°C
Filters, Optical	+80°C
Gage, Strain	-240°C to +427°C
Gears	
Gyro, Rate	-54°C to +93°C
Heads, Erase / Record / Reproduce	
Headphones, Crystal	-40°C to +65°C
Headphones, Magnetic	-40°C to +65°C
Inductors	
Insulators, Ceramic	+1370°C
Insulators, Thermosetting Plastic	-195°C to +93°C
Insulators, Polyethylene	-200°C to +250°C
Insulators, Polyurethane	-73°C to +121°C
Iris	
Jacks	
Lamps	-55°C to +177°C
Lens	
Lubricant	
Oil, Low Torque, Low speed, G.E. Versilube F44	-73°C to +177°C
Grease, High Speed	-54°C to +177°C
Molysulphide Bronze	-201°C to +260°C

Magnets	-184°C to +316°C
Micro-Circuits	-55°C to +150°C
Microphones	-40°C to +65°C
Microwave Planar Triodes	
Motor, AC	-55°C to +125°C
Motor, DC	-55°C to +125°C
Odometer	
Oscillators, Tuning Fork	-55°C to +85°C
Pulleys	
Reactance Tube	
Relay, Contact	-65°C to +125°C
Relay, Crystal Can	-70°C to +160°C
Relay, Differential	-65°C to +125°C
Relay, Frequency Selective	-40°C to +85°C
Relay, Latching	-65°C to +125°C
Relay, Mercury	-65°C to +125°C
Relay, Miniature Reed	-20°C to +95°C
Relay, Solid State	-65°C to +125°C
Relay, Time Delay	-65°C to +125°C
Resistors, Carbon Deposited	-55°C to +150°C
Resistors, Conductive Plastic	-65°C to +150°C
Resistors, Film, Metal	-55°C to +165°C
Resistors, Glass	-65°C to +400°C
Resistors, Wire Wound	-65°C to +150°C
Shutter	
Solenoid	-54°C to +74°C
Speaker	
Springs	

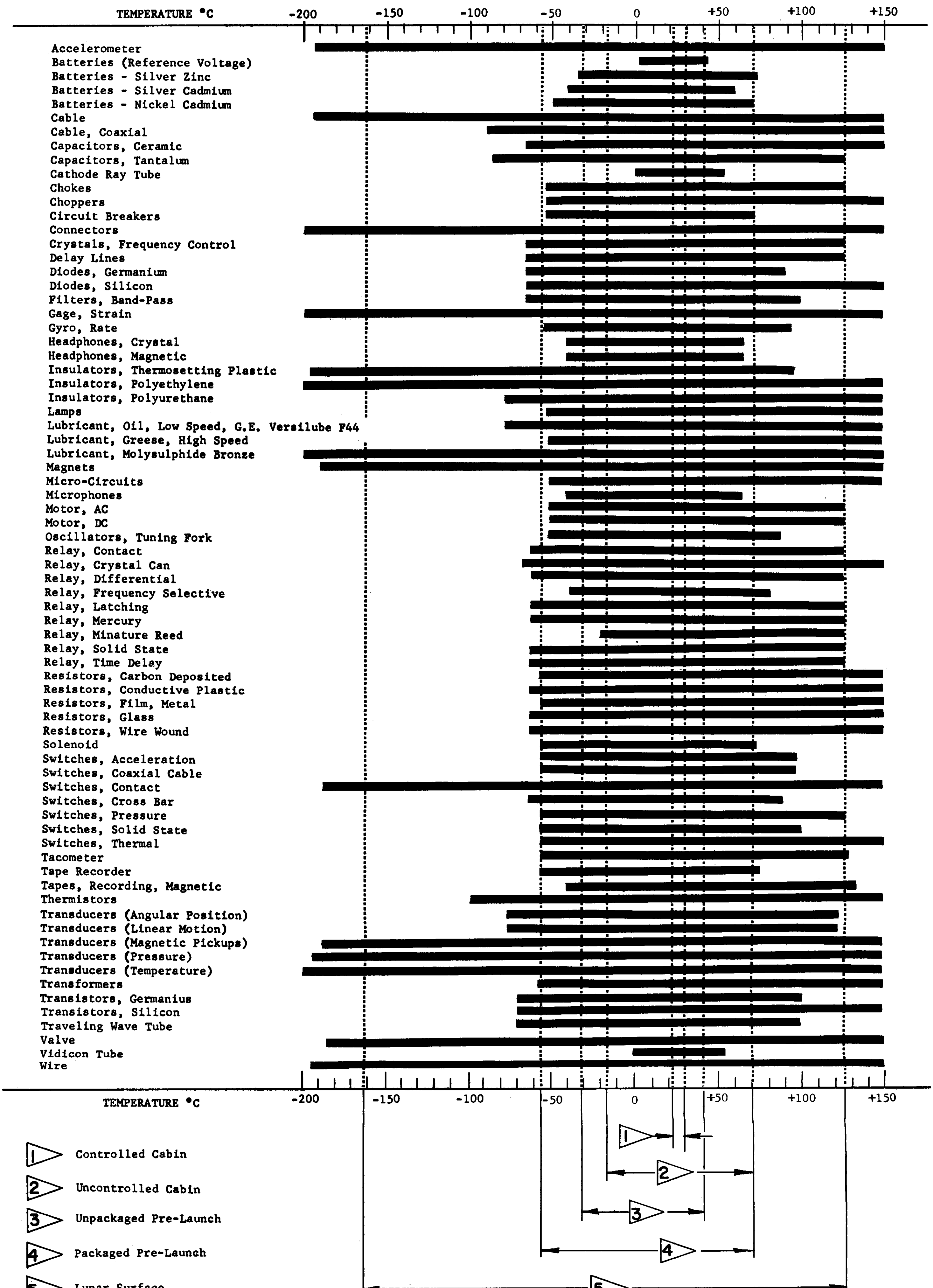
Switches, Acceleration	-54°C to +93°C
Switches, Coaxial Cable	-55°C to +90°C
Switches, Contact	-184°C to +149°C
Switches, Cross Bar	-62°C to +85°C
Switches, Pressure	-54°C to +121°C
Switches, Solid State	-55°C to +100°C
Switches, Thermal	-54°C to +232°C
Tacometer	-55°C to +125°C
Tape Recorder	-54°C to +74°C
Tapes, Recording, Magnetic	-40°C to +121°C
Thermistors	-100°C to +300°C
Transducers (Angular Position)	-73°C to +121°C
Transducers (Linear Motion)	-73°C to +121°C
Transducers (Magnetic Pickups)	-184°C to +316°C
Transducers (Pressure)	-195°C to +260°C
Transducers (Temperature)	-240°C to +788°C
Transformers	-55°C to +150°C
Transistors, Germanium	-65°C to +100°C
Transistors, Silicon	-65°C to +200°C
Traveling Wave Tube	-65°C to +100°C
Valve	-184°C to +149°C
Vidicon Tube	0°C to +55°C
Wire	-195°C to +316°C

5.0 COMPARISON OF NON-OPERATING TEMPERATURE LIMITS WITH MOLAB ENVIRONMENT

Figure 2 shows the non-operating temperature ranges of the MOLAB components and the temperature extremes of the MOLAB environment. The most favorable environment will be within the MOLAB cabin during the manned periods when the temperature will range between 21°C and 27°C. As would be expected, all of the MOLAB components will withstand these temperatures.

During the pre-launch period, and in the packaged condition, the temperatures vary from - 54° to + 71°C. These temperatures will be too extreme for some of the components. The three common high-capacity batteries (silver - zinc, silver - cadmium, and nickel -cadmium) should not be exposed to temperatures as low as - 54°C. The high temperature of + 71°C also is more extreme than the silver - cadmium battery should be exposed to. If batteries are used they probably will be shipped to the launch site separately from the MOLAB in order that special care may be taken in their handling.

Another component that will not withstand the pre-launch packaged period is the cathode ray tube. This possibly could be installed at the launch site if such provisions were made during the design of the equipment.



NON OPERATING TEMPERATURE LIMITS MOLAB COMPONENTS

FIGURE 2

The headphones and microphones have a temperature limitation of -40°C to +65°C. They probably will be loose equipment and could be installed easily at the launch site. It also is possible that the temperature limitations of these components can be extended.

The magnetic tape for the tape recorder has a low temperature limit of -40°C. This is another component which probably could be installed at the launch site.

The vidicon tube will be just as sensitive as the cathode ray tube, and probably should be handled in the same manner.

During the pre-launch period and in the unpackaged condition the temperatures may vary from -31°C to +43°C. There are three components which should not be exposed to the -31°C temperature. These are the silver-zinc battery, the cathode ray tube, and the vidicon tube. Since the MOLAB will still be on the earth when these temperatures occur, it should not be hard to control the environment of these components.

During the launch and boost period of the mission, the temperatures within the uncontrolled cabin and the equipment bay will be between -18°C and +71°C. These temperatures will exceed the upper limit of the silver-cadmium and nickel-cadmium batteries, the headphones, and the microphones. They exceed both the upper and lower limits of the cathode ray tube and the vidicon tube. Either some type of temperature control will have to be provided for these components or components will have to be developed which will withstand these temperatures.

During the flight from the earth to the moon, the temperatures within the uncontrolled cabin and the equipment bay will be the same as they were during the launch and boost period. This also is true during the lunar descent and the lunar stay periods. The components that required temperature control during the launch and boost periods will also require temperature control during these periods.

It should be noted that the conclusions reached here are dependent upon the predicted temperatures within the MOLAB. These temperatures may be considerably different from those that actually will exist since the configuration design and its passive insulating charactristics have not been finalized.

It probably will be necessary to expose some electronic components directly on the lunar surface. This would be true of equipment used to make scientific measurements of lunar surface characteristics. Although no effort has been made to include the components used for scientific measurements in this report, it is possible that some of the components included here could be used for that purpose. Usually, the allowable temperature extremes for these types of components are greater because their use has been required previously in other extreme environmental conditions.

Listed below are some of the components which may be capable of withstanding the lunar surface temperatures:

Accelerometer

Cable

Connectors

Gage, Strain

Insulaters

Magnets

Switches, Contact

Transducers, Magnetic Pickups

Transducers, Pressure

Transducers, Temperature

Wire

6.0 OPERATING TEMPERATURE LIMITS

The determination of the operating temperature limits for particular types of components is difficult without actually establishing the design of the electronic equipment.

There are many variables other than the characteristics of the electronic component itself which will determine the allowable operating temperature. One factor is the reliability of the component (mean time between failure) as it varies with the operating temperature of the component. The required reliability for the component will be dependent upon the number of components in the system, the required life of the system, and the consequences of failure.

Another factor which must be established is that element which constitutes a failure. A slight change in operating characteristics of a component may render it useless in one application but be of no significant consequence in another.

There necessarily will be a trade-off between the operating temperatures of the components and the number of components in the system. Usually the operating temperature can be reduced by adding additional components to the system. The lower operating temperature will tend to increase the reliability, but the additional components will tend to reduce it.

It would be advantageous if a mathematical model were set up to include all of the parameters effecting the operating temperatures of the components. This could be a very useful tool in the analyzation of design proposals.

An attempt will be made in this section to establish some of the known relationships between the various parameters, and, also, to show areas where more investigation will have to be conducted.

The following parameters appear to determine the component operating temperatures:

R	Reliability (The probability that failure will occur)
N	Number of components in the system
t	Required operating time
T_d	Temperature of heat dissipating surface
θ_{CD}	Thermal resistance between the critical component element and the heat dissipating surface
T_c	Temperature of critical component element
r	Redundancy factor

$$R = (f)\ N, t, T_c, r$$

$$T_c = (f)\ T_d,\ \theta_{CD}$$

$$\therefore R = (f)\ N, t, r, T_d,\ \theta_{CD}$$

The general equation for the reliability of an individual component is:

$$R(t) = e^{\int_0^t \lambda dt}$$

where
R = Reliability (same as above)
e = Natural log 2.718
λ = Chance failure rate
t = Operating time

if λ were a constant, this equation would be simply:

$$R(t) = e^{-\lambda t}$$

However, it is known that λ is some function of temperature and also of other environmental characteristics such as shock and vibration. It also may be a function of operating time. As mentioned previously, it will be assumed that the environmental effects other than temperature can be reduced or eliminated by the design of the equipment.

As long as only one component is considered, the equation remains fairly simple; however, an electronic system consists of many components, and even different systems will be inter-related. In an electronic system with a large number of components, it can be assumed that the components will operate in series, which means that if any one component fails the whole system fails. If there is a redundancy within the system, the failure rate of the redundant system still can be considered a unit in series with the system.

The total reliability of a system with series components is equal to the product of all the component reliabilities.

$$R_s = R_1 \cdot R_2 \cdot R_3 \cdot R_4 \cdot \cdot \cdot \cdot \cdot R_n$$

or by substituting the preceding equation:

$$R_s = e^{-\lambda_1 t} \cdot e^{-\lambda_2 t} \cdot e^{-\lambda_3 t} \cdot e^{-\lambda_4 t} \cdot \cdot \cdot e^{-\lambda_n t}$$

$$= e^{-(\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 \cdots \lambda_n)t}$$

It can be seen that R_s, the system reliability, will approach one or 100 percent, as the factor $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 \cdots \lambda_n$ approaches zero. The whole equation reduces to the simple addition of failure rates. The maximum reliability will be obtained when the sum of the individual component failure rates is a minimum.

The determination of the individual component failure rates is the difficult problem. This type of information has not become available until recently and still is not available for many components. The information that is obtainable is difficult to correlate with the lunar environment. For example, often the component failure rate is plotted against the ambient air temperature. Since there is no air on the moon, and the MOLAB cabin atmosphere will be quite different from that of the atmosphere on the earth, the data will have to be revised to make it useable.

Another problem is obtaining low temperature failure rates. Most failure rate curves stop at 0° or +20°C. The failure rate is still decreasing at these temperatures. Data should be obtained for temperatures that are low enough to indicate the point of minimum failure rate.

7.0 COMPARISON OF OPERATING TEMPERATURE LIMITS WITH THE MOLAB ENVIRONMENT

Although no actual operating temperature limits have been established for the MOLAB components, an attempt will be made in this section to discuss the relationship between the operating temperatures and the MOLAB environment.

During the manned phase of the MOLAB mission, the MOLAB cabin temperature will be maintained between +21°C and +27°C. These temperatures will be within the operating limits of the electronic components, but it is possibl that the electronic components will not be at the most reliable operating point at this temperature. Since the failure rate for most components is still decreasing at temperatures of 0° or 20°C, it would be desirable to keep the electronic components at a lower-than-cabin temperature.

It is possible that these lower temperatures can be obtained without any increase in mass or power requirement. In section 3.0, the lunar surface temperatures are stated to range from -162°C to +127°C. The average temperature of these two extremes is -17.5°C. By proper location of the electronic equipment with respect to the controlled cabin and the MOLAB exterior, and the intelligent use of insulating materials, it should be possible to obtain the temperature range desired for the electronic equipment. It appears that regardless of the period of the lunar day, it always will be possible to reject heat from the MOLAB. Even at lunar noon, when the lunar surface would be at its maximum temperature, it is possible to radiate heat to space, which is at 0°K.

The most critical period may be during the lunar night when the MOLAB is unmanned. This could be the most costly period of the MOLAB mission, since power may be required to prevent the temperature of the MOLAB from going below a certain point. Even though some components may withstand the low temperatures when not operating, they may not operate properly at these temperatures. The internal heating of the part may bring it up to operating temperature, but it may not be possible to live with its operation until this point is reached. For example, the resistance of a resistor may be so low at low temperature that it will allow an excessive current to pass through another part and cause it to fail.

The MOLAB can never be completely dormant, or there will be no means for communication with it. There must be a receiver of some type operating continuously, and also some portion of the power supply operating to power the receiver. There doubtlessly will be other equipment which also will have to operate continuously. There will necessarily be some temperature control required during all of the MOLAB's lunar stay.

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